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SECOND REPORT

ON

THE FRUIT EXPERIMENTS AT PŪSA

BY

ALBERT HOWARD, M.A. (Cantab.), A.R.C.S. (Lond.), F.L.S.,
IMPERIAL ECONOMIC BOTANIST.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
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SECOND REPORT ON THE FRUIT EXPERIMENTS AT PŪSA.

I. INTRODUCTORY.

THE Pūsa fruit experiments were laid down in 1905 and the first report,[1] giving an account of the experimental scheme, was published in 1907. The present report[1] deals with the results so far obtained and the general experience gained in fruit-growing in the plains of India. It is hoped that these results will be of use to those engaged in fruit-growing for profit in this country.

Several important general matters, omitted in the first report for want of the necessary information, are given below. These relate to the rainfall, temperature and humidity, and also to the soil. I am indebted to Mr. H. E. Annett, Officiating Imperial Agricultural Chemist, for the meteorological tables and for the soil analyses.

The climate of Pūsa is typical of that of North Bihār and is characterised by three distinct kinds of weather. During the months of November, December and January the weather is too cold for the growth of fruit trees, and these months form the annual testing period. From March to June the weather is hot, practically rainless, and during this period the dry westerly winds are the characteristic feature of the hot weather period. The monsoon phase, characterised by heavy rain, easterly winds and high humidity, extends from June to the beginning of October, while during the rest of this month the temperature rapidly falls, forming a connecting link with the cold weather. The monthly rainfall, the maximum and minimum shade temperatures and the mean monthly humidity are given in the following table :—

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[1] Howard, *Bulletin No. 4, Agricultural Research Institute, Pūsa*, 1907.

Meteorological Data.

Month and year.	Rainfall in inches.	Mean humidity.	Shade temperature.		Remarks.
			Maximum.	Minimum.	
January 1906	. .	78	76·8	46·4	
February „	1·29	82	82·0	47·3	
March „	0·21	66	94·8	44·3	Not recorded on March 3rd and 4th.
April „	*Nil.*	40	109·7	62·9	
May „	1·93	67	110·2	67·3	
June „	5·48	76	107·6	74·8	
July „	11·99	88	96·3	77·0	
August „	24·81	89	91·0	75·6	
September „	3·06	83	95·6	76·2	
October „	·57	83	91·6	66·3	
November „	*Nil.*	81	89·2	53·8	
December „	*Nil.*	85	Not recorded.	40·9	
January 1907	*Nil.*	89	Not recorded.	45·3	
February „	1·22	87	Do.	47·7	
March „	1·77	75	Do.	51·7	
April „	·89	66	102·1	56·7	
May „	·33	64	105·0	65·5	
June „	6·88	82	106·5	71·3	
July „	6·67	92	94·4	75·7	
August „	6·14	88	94·5	75·9	
September „	14·80	89	94·4	73·6	
October „	*Nil.*	85	92·9	59·3	
November „	*Nil.*	83	87·6	52·0	
December „	*Nil.*	81	81·7	42·5	
TOTAL	38·7				

1. Maximum and minimum temperatures were recorded from 23rd January 1906 only.

2. Humidity was recorded from 29th January 1906 only.

3. Rainfall prior to 16th February 1906 not recorded.

Rainfall from 1st January 1906 to 15th February 1906 at Muzaffarpur = 0·62″.

„ „ „ „ „ Darbhangā = 0·50″.

Month and year.	Rainfall in inches.	Mean humidity.	Shade temperature.		Remarks.
			Maximum.	Minimum.	
January 1908	0·47	86	78·7	35·7	
February ,,	2·27	79	85·6	44·4	
March ,,	·10	57	103·8	47·2	
April ,,	*Nil.*	52	109·4	67·7	
May ,,	·92	69	110·9	67·4	
June ,,	1·48	79	108·7	73·1	
July ,,	7·24	84	102·6	74·6	
August ,,	3·85	83	98·8	74·0	
September ,,	4·97	92	98·7	73·2	
October ,,	·58	73	97·8	57·9	
November ,,	*Nil.*	72	90·3	49·3	
December ,,	·04	82	81·8	40·1	
TOTAL	21·92				
January 1909	·11	76	85·2	39·8	
February ,,	·23	67	92·8	37·9	
March ,,	*Nil.*	33	105·4	51·1	
April ,,	3·47	67	105·0	62·4	
May ,,	1·34	65	109·5	68·2	
June ,,	28·96	86	103·0	73·0	
July ,,	10·08	87	94·6	75·5	

The most striking characteristics of the soil of the Pūsa Estate are the high percentage of calcium carbonate and the small amount of phosphoric acid. The physical character of the soil and its suitability for various crops depends largely on position. The high-lying lands are, as a rule, much opener in texture, with a better subsoil drainage than the heavier low-lying lands. The extreme limit carries one to the low rice lands which are often flooded during the monsoon. The growth of fruit trees is practically restricted to the higher opener and better drained soils. The area under the fruit experiments at Pūsa consists of high-lying well drained land with a gentle slope towards the south. It is perhaps best described as a light loam and the differences in chemical composition and physical analysis between the plots is not very great as will be seen in the following tables :—

Chemical and Mechanical Analyses of Pūsa Soil

Chemical Analyses.

	Peach plot.	Loquat plot.
	%	%
* Organic matter and combined water . .	1·23	0·98
Sand	57·19	56·99
Fe_2O_3	1·85	2·35
Al_2O_3	1·83	3·40
P_2O_5	0·08	0·10
CaO	19·11	19·07
CO_2	15·29	15·81
MgO	1·37	1·05
K_2O	0·40	0·56
Na_2O	0·39	0·13
Available K_2O	0·00035	0·00026
,, P_2O_5	0·0054	0·0046
* Containing Nitrogen	0·025	0·023

Mechanical Analyses.

Diameter of particles.	Peach plot.	Loquat plot.
	%	%
Above ·032 mm. (sand)	26·1	26·2
·032—·016 mm.	49·4	47·7
·016—·008 mm.	8·5	8·9
·008—·004 mm.	6·5	6·3
·004—·002 mm.	5·6	6·2
Below ·002 mm. (clay)	2·2	1·2

2. METHODS OF PLANTING.

Since the year 1905, when the Pūsa fruit experiments were started, considerable practical experience has been gained on the subject of the planting of trees in the alluvium. A planting experiment was also started with oranges and peaches, but the abnormal rainfall of 1906 and 1907 waterlogged the soil to such an extent that a good many of the young trees were killed and the experiment had to be abandoned before any results were obtained.

Some of the plots at Pūsa were planted in holes during and after the monsoon of 1905. The holes were about 4 feet in diameter and 2½ feet deep and the young trees were watered when necessary by means of a porous earthen pot (*ghurra*) kept filled with water, sunk in the earth at the side of the tree. The young freshly planted trees were shaded by means of conical millet straw covers kept open on the north side.

This method was found to have several disadvantages. When planted in the monsoon, there is a danger of loss by waterlogging, especially in the case of citrus plants and peaches. Further, little or no immediate growth takes place when young trees are planted during or after the monsoon, as the operation naturally checks growth and time is taken to recover. From November till the middle of February the weather is too cold for growth to take place, so that after June or July any freshly planted trees do little more than maintain themselves for the next eight months. During this period there is the risk of loss by waterlogging, by drought, by white-ants (*Termites*) and damage by leaf-eating insects. Watering by earthen *ghurras* sunk at the side of the plant was not found to be very satisfactory. It is difficult to sink the earthen pots in such a way as to avoid air spaces between the pot and the soil, the presence of the *ghurra* interferes with symmetrical root development, while the supply of moisture possible by this method is not more than sufficient to keep young trees alive during the hot weather. The conical shelters are also disadvantageous in attracting burrowing rats which sometimes devoured the young trees.

In 1906, irrigation facilities were available for the whole of the fruit experiments at Pūsa and a new system of planting was devised by which the disadvantages mentioned above were entirely avoided, and by which the trees were established during the year of planting. The new method consisted in planting at the end of the cold weather at the beginning of February. All the fruit trees of the plains of India make no growth during the months of December and January, and deciduous trees like the peach, plum and custard apple often drop their leaves entirely. After the first week in February the weather changes, the temperature rises and a large amount of growth takes place which is continued during the first part of the hot weather. A second period of growth takes place at the beginning of the monsoon in May and June. By planting just before the first hot weather period of growth, it should be possible to take advantage of this and to get the trees established before the heavy rains of July and August. Experience proved that this is the case and the trees planted at the end of the cold weather have been established with ease and with practically no loss.

The holes are dug during the autumn and left open till just before planting time so that the soil can be thoroughly aërated. In the middle of January they are filled in, care being taken to consolidate the soil as much as possible by treading so as to limit future subsidence. The holes are not filled to the level of the ground, but are raised in the form of a circular mound about four or five inches high in the centre where the young tree is to be planted. Irrigation furrows are now laid off parallel to the rows of trees, and furrow rings from 3 to 4 feet in diameter are made round each mound. These rings are then joined up to the longitudinal furrows by short connecting trenches and the rings are filled with water two or three times till the whole of the soil within the ring is moistened by lateral seepage (page 9). Such an irrigation produces a thorough shrinkage and consolidation of the soil and prevents future subsidence. It is only by watering in this way that alluvial soils are properly compacted. Even after treading the new earth will sink during the monsoon and carry any tree planted in it below the ground level, leaving a saucer-like depression into which rain-water drains and produces waterlogging. Young citrus trees and peaches are easily killed in this manner during the first monsoon. After this previous irrigation and any subsidence has been made up by the addition of new earth, the trees are very firmly planted two or three days after the last watering. Care must be taken to plant very firmly as loosely planted trees never thrive and easily dry out. Planting firmly in well moistened earth results in an immediate development of the root system followed by the growth of new leaves and new wood.[1] Abundance of moisture is available by this system of irrigation and the young trees develop rapidly and are not merely kept alive as in the *ghurra* system of watering. The young trees are not shaded during the hot weather and subsequent irrigation is carried on by filling the rings. In this way full advantage is taken of the early hot weather growth and the trees suffer no check, but begin to grow and establish from the moment of planting. By the time the heavy rains of July and August are encountered the trees are strong enough to withstand any temporary waterlogging.

In 1908, an experiment was commenced to test a new method of raising budded orange trees. The variety selected was the loose skinned Nāgpur orange budded on sweet *chickna* lime stocks. As is well known, the orange tree suffers a considerable check on being transplanted in the ordinary way and often several months elapse before it begins to form new wood. In order to obviate this, the sweet lime stocks were very carefully taken up with large balls of earth and without injuring the tap root, in November, and planted out in the plots before budding the following March. By this time the limes were well established and were growing vigorously. At the same time another similar set of lime stocks were budded in the nursery and planted out in June at the beginning of the monsoon. It will be interesting to compare the development of the two sets of trees and the time taken in coming into bearing.

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[1] The advantages observed with firm planting agree with what has been found by the Duke of Bedford and S. U. Pickering at Woburn in England, where ramming the earth round the roots of freshly planted trees was found to promote the development of adventitious roots by creating an intimate contact between the roots and the soil. (*Ninth Report of the Woburn Experimental Fruit Farm, 1908.*)

3. IRRIGATION.

One of the first questions that had to be considered in the fruit experiments at Pūsa was the best means of applying the irrigation water. Several considerations have to be borne in mind in devising a suitable system. In the first place, the trees must be watered as evenly as possible, the unirrigated plots must be cut off from the irrigated and lateral seepage from the latter to the former prevented. Again the slope of the land has to be considered and the character of the soil. The Pūsa soil is not adapted to surface flooding as it runs together very easily resulting in the destruction of the tilth and the formation of a surface skin (*papri*). Surface flooding besides involving a large amount of subsequent tillage has several disadvantages, notably the great loss of water by evaporation and the slowness of percolation except in sandy soils. Surface flooding being obviously excluded some form of furrow irrigation seemed most likely to succeed. Furrow irrigation, in case the trenches are not too shallow, ensures a deep penetration of the water, leads to the minimum loss by evaporation and moreover does not destroy the tilth and the surface mulch of loose dry soil which it is so desirable to maintain during the hot weather.

Several systems of furrow irrigation are possible with fruit trees, all of which seem to have advantages in certain cases. The basin system in which a shallow circular hole is excavated round each tree and the holes joined up by a trench, as in Fig. 1, is widely adopted by the cultivators in India for the watering of shrubs and trees.

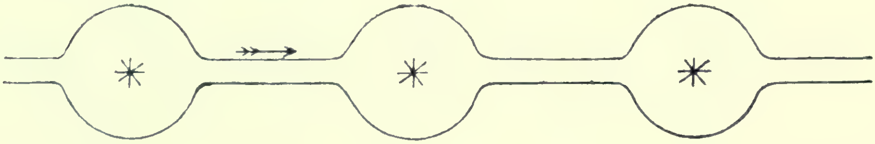

FIG. 1.—Basin irrigation.

While a good system for established trees, it is not so successful with young trees planted in such fine soils as those of Pūsa where, in order to prevent waterlogging by the excessive rainfall in July and August, it is desirable to plant the young trees on slightly raised mounds. Citrus trees are especially liable to the "collar rot" disease and therefore would not be benefited by waterlogging

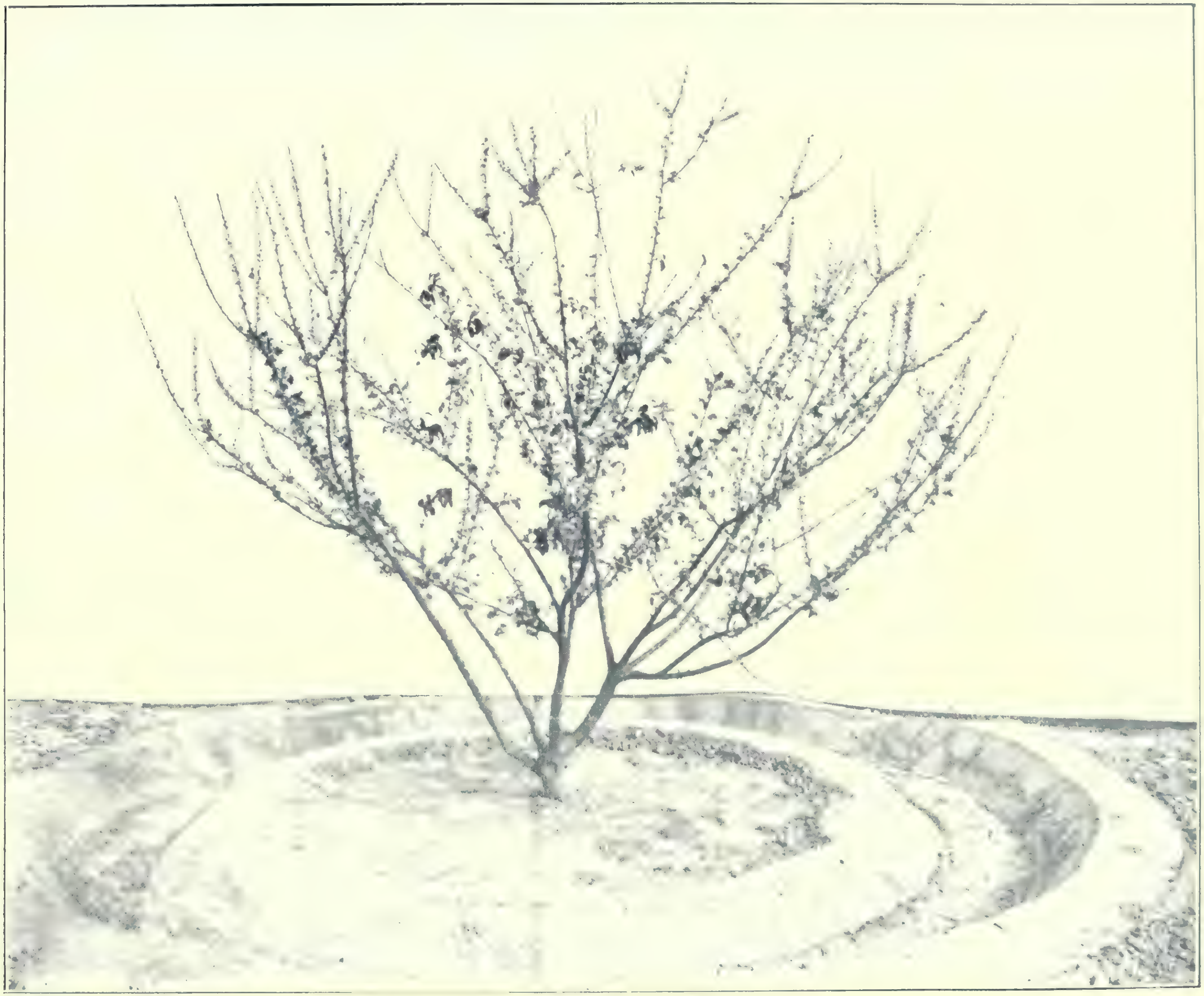

Plate I.

The Furrow-Ring Method of Irrigation at Pūsa.

round the base of the stem. From observations in many fruit gardens in India it appears very likely that young trees are often harmed by this system of watering. Furrows between the rows of trees, as is practised in California, does not seem to be a good system for young trees as the water is not applied near enough to the roots. A method of ring and furrow irrigation was therefore adopted by which the water was applied approximately above the feeding roots. The method is as follows. A trench about nine inches wide and five or six inches deep is laid off parallel to the rows of trees. Each tree is then surrounded by a similar furrow ring, the position of the ring corresponding to the outer spread of the branches (Plate 1). In newly planted trees the inside diameter of the furrow ring is 3 to 4 feet. The rings are joined up to the longitudinal trench by short connecting trenches by means of which the rings can be cut off by an earth dam from the longitudinal trench. The following diagram will make the arrangement clear.

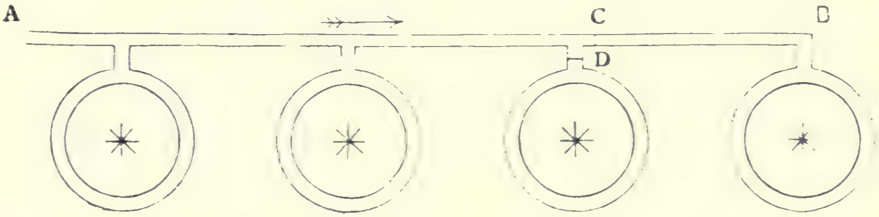

Fig. 2.—Furrow-ring irrigation.

In carrying out this system in practice, water is allowed to run down the trench AB to B, the furthest point from the main distributing channels. The last ring is then opened and allowed to fill. As soon as this takes place, the main trench is filled at C with a dam of earth and the connection at D is opened. The second ring is now filled and so on. In this way there is no stoppage of work and the tree is not only supplied by the water in the ring, but also by that in the section of the trench CB. Before the monsoon the rings are filled up and re-made with a larger diameter, according to the growth of the tree, at the beginning of the next hot weather.

In planting new trees this system of irrigation has been found advantageous. After the holes have been dug for the trees and filled in, the rings are made and the irrigation water run into these two or three times *before* planting. By this means only can the soil be properly compacted and subsequent shrinkage and subsidence prevented.

This system of irrigation has proved most useful in connection with the manuring of trees. One of the difficulties in applying manure to fruit trees in India is the subsequent damage done by white-ants (*Termites*) which are attracted by the organic matter of the manure and subsequently turn their attention to the tree and destroy it. If the trees are manured just before the rings are made and if care is taken to apply the manure only to the ring of soil underneath the outside branches, the first watering not only tends to rot the manure, but also to drive off the white-ants.

In carrying out the ring system of irrigation it has been found better in practice to fill the rings two or three times in succession every two or three weeks rather than to fill them once every week. A deeper penetration of the water is obtained in this manner and the loss by evaporation is greatly reduced. This method besides its economy of water enables the trees to be evenly watered, is easy to carry out and does not destroy the tilth or cause the surface mulch of dry soil to compact.

Experiments have been planned and will be carried on at Pūsa during the next few years to determine whether in the case of large established trees such as peaches and guavas furrow irrigation will still be advantageous, or whether it will be better to substitute the basin method of irrigation for such trees. Hilgard,[1] in describing the basin system of watering trees, states that " the water thus supplied of course percolates immediately around the trunk first, and in practice is found to follow also the large roots; so that it goes precisely where it is most wanted, besides forming a vertical body of moist soil reaching to considerable depth, where it is desirable the root system should follow. By this deep penetration to the natural moisture in the depths of the soil, comparatively small quantities of water produce very marked results." These statements of course refer particularly to Californian soils, and it has yet to be shown whether in alluvial soils like those of Pūsa similar results will be obtained.

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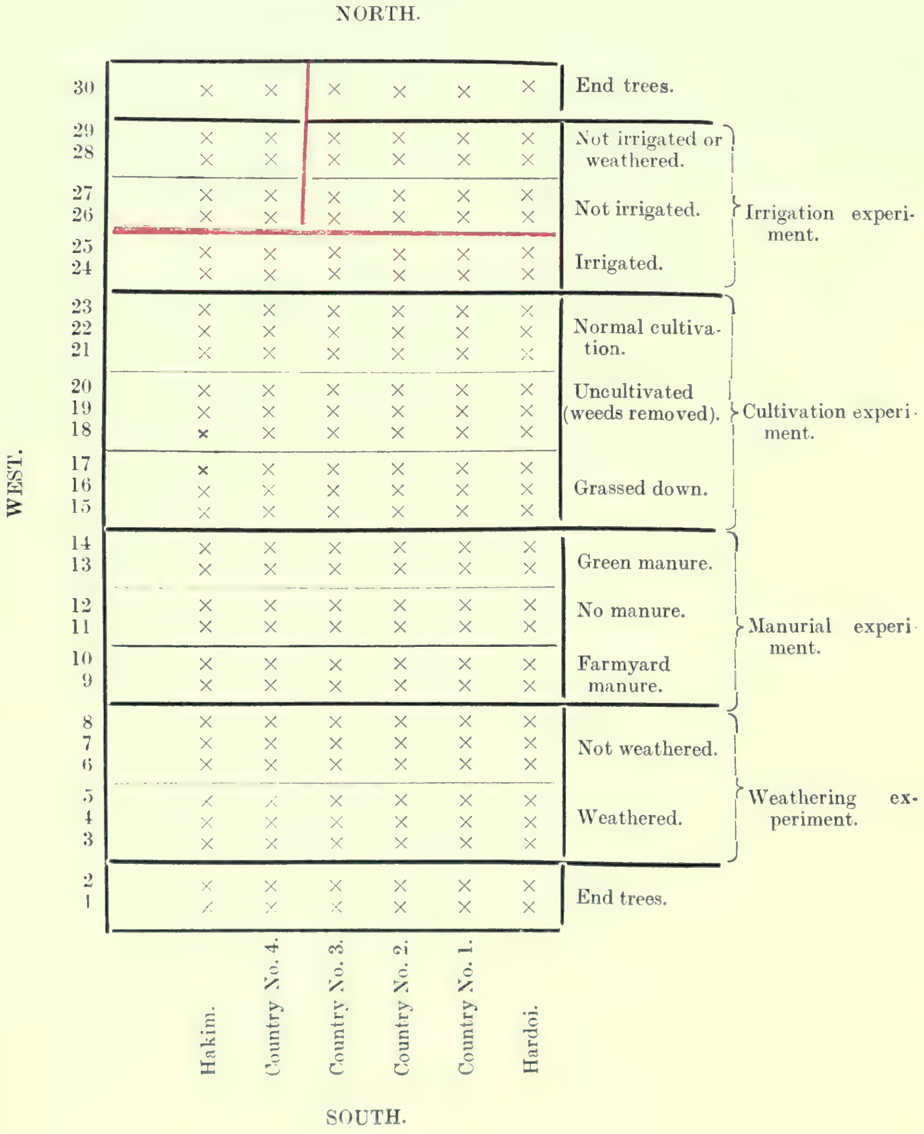
[1] Hilgard, *Soils, their formation, properties, composition, and relations to climate and plant growth in the humid and arid regions*, 1906, p. 243.

In order to prevent seepage from the irrigation trenches at the north of the plots and to carry the water through the non-irrigated plots without affecting these by seepage, watertight masonry channels lined with cement have been provided. The method is indicated in the following plan of one of the plots where the cement channels are shown in red.

Plan of Western Peach Plot.

20′ in rows, 25′ between rows.



4. THE TILLAGE OF FRUIT LANDS IN INDIA.

The amount of tillage necessary for the successful production of fruit and the condition of the surface are subjects which have long exercised the minds of fruit-growers in Europe and North America. Many growers, especially in the United States, strongly advocate the clean culture system followed in the summer by a cover crop to prevent wash and to add organic matter to the soil. In England, at the present time, it is customary in new plantations to use the clean culture system either with or without bush fruits between the rows of the permanent trees. Where bush fruits are grown these are removed as the larger trees increase in size. On the other hand, many of the best orchards in the country are under grass while there are strong advocates of this system in the United States.

In India, little or no attention seems to have been paid either to the tillage of fruit lands or to the best condition in which the surface should be maintained. Some of the fruit plantations in the country are under grass, others are to a large extent uncultivated, the surface being covered with weeds and grass. In some cases the trees are so closely planted that they form a dense overhead canopy like that of a forest under which no surface growth is possible. Vegetables or bananas are generally grown between the young trees, the object of the cultivator being to take off the largest crop possible. It is not surprising that under these circumstances the fruit trees have a neglected, stunted and half starved appearance. In the older plantations, the thickly planted trees are drawn and spindly and often bear but few fruits. Cultivation is often restricted to one digging in the cold weather while there is generally little or no cultivation or weeding during the monsoon. The tillage of fruit plantations such as is understood and practised in Europe and North America is still undreamt of in India. It is not surprising therefore that the produce of the average Indian fruit garden in the plains is so exceedingly poor.

The Cultivation Experiments at Pūsa.

The subject of the tillage of fruit trees in India seemed one which would quickly repay experimental study, and accordingly, when the Pūsa fruit experiments were started in 1905, a cultivation experiment was included for all the kinds grown. In all cases this experiment consisted of three plots as follows :—

(1) Normal cultivation.
(2) Uncultivated (weeds removed).
(3) Grassed down.

In the normal cultivation plot, of which the tillage is that ordinarily adopted at Pūsa, the best practice adopted in England and the United States has been followed. The surface is kept free from weeds, the land is well cultivated in the cold weather and a loose surface mulch is maintained. In this way there is no loss of moisture or of food materials through weeds, the soil moisture is conserved and the open texture of the soil enables the maximum amount of rainfall to be absorbed. While the trees are young a cover crop of *san* (*Crotalaria juncea*) is grown and ploughed in during the rains which adds humus to the soil and also prevents rain wash.

The uncultivated plot is kept as free as possible from weeds. It is not possible however with the labour available to keep this plot absolutely weed-free on account of the rapid growth of the common red weed of the plains (*Euphorbia thymifolia* Burm.) which thrives abundantly on the hard and beaten surface of these plots.

The turf on the grassed down plot practically consists of only one species (*Cynodon dactylon* Pers.), the common *dub* grass of India. This grass is kept free from weeds and is maintained as far as possible in pure culture. It is kept closely cut with a lawnmower and the cut grass is allowed to remain on the surface. The grassed down plots are therefore kept like a lawn the whole year round.

The cultivation experiment consisting of the three plots described above was not started immediately the trees were planted, but only when they were well established. In the case of the plots of citrus, plum, custard apple, loquat, peach, guava and fig the grass plot was laid down in June and July 1907 from which date the no-cultivation plot has not been tilled. Up to the middle of 1907 all these plots were normally tilled and a cover crop of *san* was grown during the early monsoon and ploughed in. In all cases the trees at the time the experiment was started were growing very vigorously and in the case of the peaches had already given a small first crop. The cultivation experiment has therefore

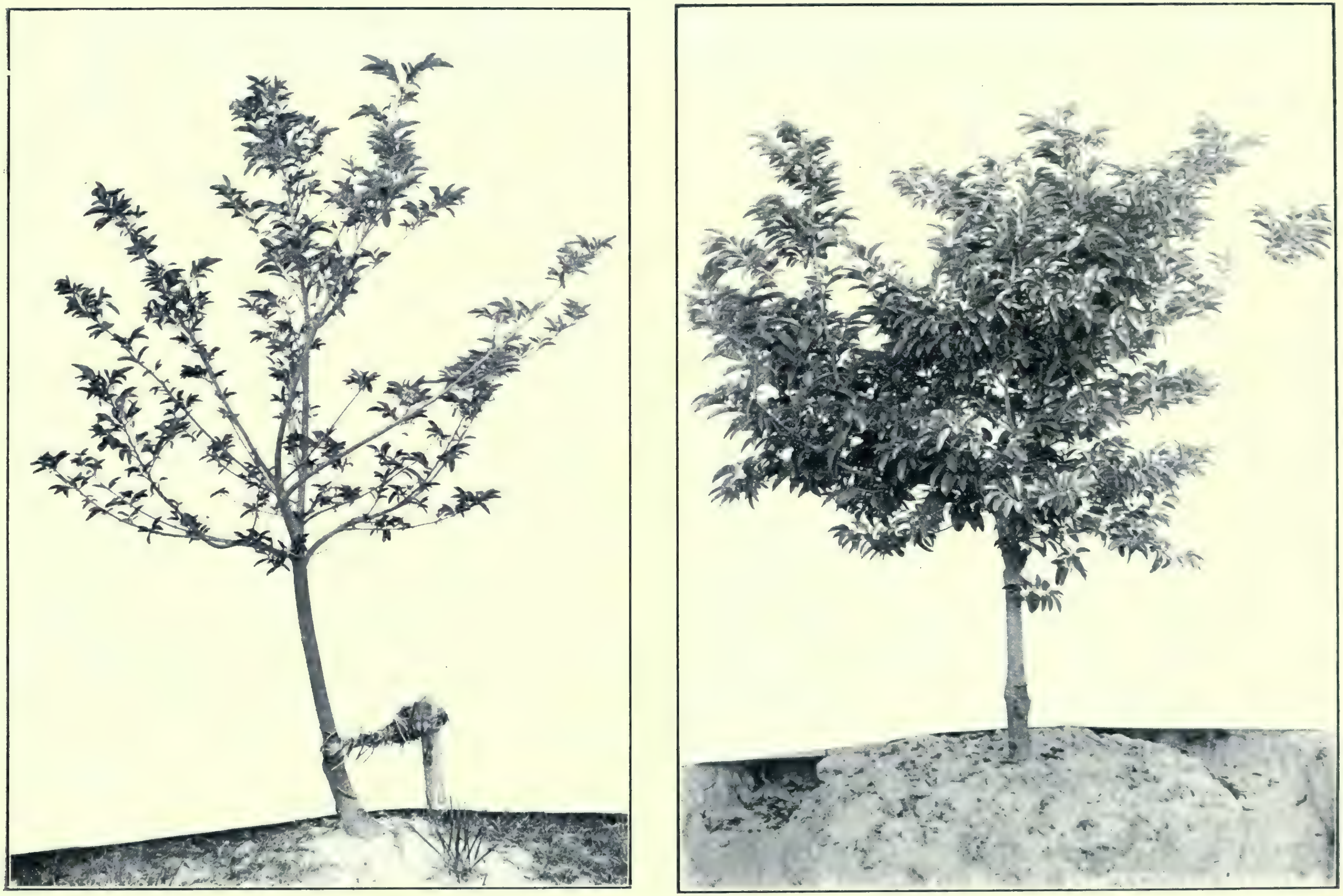


PLATE 2.

GRASSED DOWN.

SURFACE CULTIVATED.

THE RESULT WITH CUSTARD APPLES OF EIGHT MONTHS GRASSING DOWN only been in operation two years, but this has sufficed to give very definite results.

The Grassed Down Plots.

There is a striking general similarity in the result of laying down these plots to grass. In the case of the limes, lemons, oranges, pumelos, plums, custard apples (Plate 2), loquats, peaches, guavas and figs the trees in the grassed plots are in a pitiable condition. Half the trees in the custard apple plot died in the early part of 1909 and the rest are now moribund. One lemon tree is dead and the rest of the grassed down citrus trees are very unhealthy. The loquats have hardly made any growth during the last year, while the peaches, guavas and figs although considerably checked and somewhat starved in appearance are affected to the least extent. This may be partly due to the fact that these trees were larger and better established before the grassing down was done and partly to the great vigour of these fruit trees at Pūsa. None of the grassed down peaches, guavas and figs seem at present likely to die, whereas it would not be surprising if a good many of the grassed citrus plants, all the custard apples and some of the loquats succumbed during the next year.

The well-being of young fruit trees in all countries is perhaps best judged by the appearance of the foliage and the growth of the young wood. Where the leaves are large, numerous, well formed, of a dark green colour and free from insect and fungoid pests, and where there is abundance of clean, vigorous, well matured new wood, there is every promise that good crops of fruit will soon be obtained. On the other hand, a sparsely developed foliage consisting of a few small yellowish leaves which are late in appearing combined with little or no development of new wood are clear indications in the case of young trees that there is something radically wrong. In such cases until a proper vegetative vigour can be produced it is idle to expect a crop. All the cultivated plots at Pūsa exhibit foliage and young wood of the most vigorous character, while the leaves of the grassed down plots are exceedingly few in number, very small in size and pale yellow in colour. The grassed down plots come into leaf and flower much later than the normally cultivated plots and the leaves are shed early. Hardly any new wood has been formed during the past year, and at the present time these trees are much smaller than those of the cultivated plots.

The differences observed in the crops are almost as great as those in the development of the trees and in the foliage. The grassed down plots although later in flowering and in coming into leaf are earlier in ripening, while the crop is small in size and in number and less juicy and of poorer flavour than that of the normally cultivated plot.

The first experiments that seem to have been published on the effect of grass on fruit trees are those conducted at the Woburn[1] Experimental Fruit Farm in England by the Duke of Bedford and S. U. Pickering. The harmful effect of grass on apple trees at Woburn was most marked and the results obtained at Pūsa agree very closely with those obtained at Woburn. The authors conclude that " this action of grass is not merely a question of starvation in any form, nor of any simple modification of the ordinary conditions under which a tree can thrive, but that the grass has some actively malignant effect on the tree, same action on it akin to direct poisoning." In the United States Hedrick[2] has recently obtained results in the case of an apple orchard near Rochester, in the State of New York, which are of considerable interest. In this experiment, which was commenced in 1903, one-half of a Baldwin apple orchard, nine and-a-half acres in extent, was grassed down, the other half being tilled. In the yield and quality of fruit, in the vigour of the foliage and young wood the tilled plot was markedly superior to the grassed down trees, and the results are a striking confirmation of the Woburn experiments. The author considers that the differences between the plots are due to the fact that there was always more moisture in the soil of the tilled plot than in the grassed down plot and that the result is a starvation effect. At the Ohio Experiment Station Green and Ballou[3] have obtained results with apples that at first appear to contradict the results obtained at Rochester, New York. In these experiments plots of apples grown under the clean culture system, under clean culture followed by a cover crop, under grass and under what is called the sod mulch system were compared. In the grassed down plots a circular space round each tree was cultivated and kept clean while in the sod mulch plots the trees are grown under grass, but this is cut several times and spread round the trees as a deep mulch. Such trees did best no doubt on account of the fact that the mulch killed the grass underneath and also conserved moisture. The grassed down plots did much worse than that under clean culture followed by a cover crop. The clean culture plot without a cover crop was abandoned on account of the loss of soil by rain wash and this circumstance seems to have prejudiced these investigators against the benefits of any tillage whatsoever.

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[1] Duke of Bedford and Pickering, *Third Report of the Woburn Fruit Farm*, 1903.

[2] Hedrick, *Bulletin No. 314, New York Agricultural Experiment Station*, 1906.

[3] Green and Ballou, *Bulletin No. 171, Ohio Agricultural Experiment Station*, 1909.

The Non-Cultivated Plot.

The effect of withholding tillage in all the plots at Pūsa has so far shown little result. For the first year no differences were observed between the normally cultivated and the non-tilled plots. At the present time however some difference can be detected, the foliage of the non-cultivated plots being a little paler green than the control plot. Possibly as time goes on the effect of cultivation will show more. One result of the withholding of tillage is however very marked, namely, the excessive development of weeds, especially of *Euphorbia thymifolia* Burm., on these plots. It is probably almost as expensive to keep these plots free from weeds as it would be to cultivate and weed them in the ordinary way.

One Disadvantage of Tillage in India.

While the frequent tillage of fruit lands in India has many obvious advantages and the clean culture system is much better than grassing down, nevertheless it is attended by one great disadvantage, namely, surface wash. As is well known the cultivator in the plains of India suffers not so much from the want of rain as from its irregular and unseasonable distribution. In most tracts the total rainfall is sufficient and often more than ample for exceedingly good crops. Unfortunately however most of the rain is useless for vegetation and often does positive harm by flooding the country and by interfering with cultivation, sowing and harvesting. Most of the rain in the plains falls during the months of July and August, and during this period it not infrequently happens that much of the rainfall is received in a few torrential falls of short duration, often at the rate of about an inch per hour.

Little wash takes place if these heavy falls are received on freshly cultivated soil, but it often happens that they succeed one another too quickly for the soil to dry enough to be again tilled with the result that very little of the rain of these later falls is absorbed, most of it running off the surface and producing either wash or flooding. As fruit trees grow best in the plains on the high-lying lands which often have a gentle slope it follows that such lands are particularly liable to rain wash. The cultivators in Bihār protect their fruit gardens from wash by embanking. A ditch is dug all round the garden and the earth is thrown up on the inside of the trench to form an embankment. The rainfall is thus prevented from running away and the soil is retained. Wash on sloping land is prevented by cutting ditches at right angles to the slope and throwing up the soil on the upper side of the ditch. In this way the slope becomes a series of terraces and the arrangement of connecting ditches acts as a drainage system.

Besides embanking, the growth of a leguminous cover crop during the monsoon is of great assistance in the prevention of surface wash. As the trees increase in size they offer more and more protection to the soil and greatly assist in breaking the force of heavy rain. Cultivation therefore must go hand in hand with suitable measures for the prevention of rain wash. Grassing down would be an ideal method of preventing wash, but such a method has been proved to be impracticable. A suitable system of embanking combined with monsoon leguminous cover crops would appear to be all that is necessary in preventing wash and so permitting a thorough system of tillage.

Some care however must be taken in the use of leguminous green manure. In the case of the peach, this annual manuring has the effect of stimulating the growth of wood to too great an extent. In the case of citrus plants however the annual growth and incorporation of a green crop of *san* has greatly benefited the trees, and in this case it appears that the annual nitrogenous manure is necessary for the healthy development of the trees.

5. THE CHOICE OF VARIETIES.

In the present backward condition of fruit-growing in India the choice of the best varieties for any particular tract is a difficult task. Until much more is known of the subject in India, the intending fruit-grower must largely solve this question for himself. India is far behind Europe and North America in this respect where the choice of varieties and their adaptation to different soils and situations and for the various needs of the market has been reduced to a fine art.

In laying out a fruit plantation it is an obvious advantage to have the trees of each variety together to facilitate picking and grading. Further, there should be several varieties so arranged as to ripen one after the other in order that the marketing period can be extended as long as possible and the labour force can cope with the work. Some varieties are more adapted than others for transport long distances by rail, a point of great importance with distant markets.

The experience so far gained at Pūsa on the choice of varieties is not yet complete enough to answer many of the questions which arise in these matters. Some information has however been obtained principally with plums and peaches. A fairly large collection of peaches and plums was made at Pūsa during 1905 and 1906 and several crops have been obtained. Of these varieties only the early ones are of any use for Bihār. Heavy crops have been borne by the early kinds, but the late sorts without exception have set no fruit. A profusion of flowers is obtained, but no setting takes place. This appears to be due to the high temperature and low humidity which prevail (on account of the dry west winds) at the time these late varieties come into flower. Copious irrigation just before flowering has no effect, no setting being obtained however the soil moisture is regulated. Of the varieties of plums and peaches which set fruit the most satisfactory are the earliest of all, those which ripen during May. The somewhat later varieties are not so satisfactory on account of the rise in humidity which often takes place during the early part of June when the moist east winds, which precede the monsoon, set in. Under such circumstances ripening peaches and plums rapidly deteriorate and fruit in this condition will not travel long distances. If varieties of peaches and plums could be obtained which ripen early in May in Bihār their cultivation would probably be most profitable. If no earlier varieties can be secured than those already at Pūsa it may be possible by a judicious arrangement of cultivation and irrigation to hasten the ripening period.

Another point to be considered in the choice of varieties is the question of hardiness or robustness. Various varieties of broad leaved Malta oranges have been planted at Pūsa, but they do not thrive and are easily destroyed by the "collar rot" disease. Of the kinds of oranges tried at Pūsa, the loose skinned Nāgpur variety (Plate 3) has done best so far. Such loose skinned oranges however do not keep any length of time and are not so easy to pack as those with tight coats.

It will be obvious from the foregoing that any intending fruit-grower will do well to bear in mind in choosing varieties for extensive cultivation the probable weather conditions at the periods of pollination and of ripening, as well as quality and robustness.

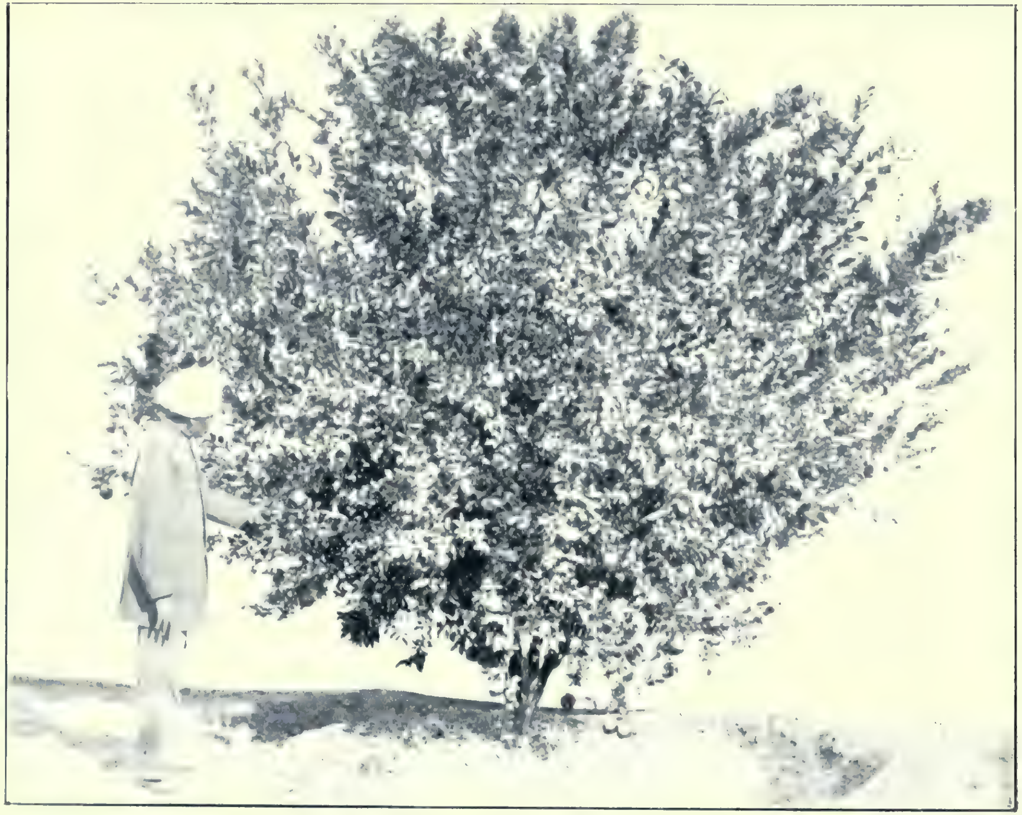

Plate 3.

A Nagpur Orange Tree—Three Years after Planting.

6. PEACH-GROWING IN BIHĀR.

"If there is any fruit that should never be neglected it is the peach; and this is why careless men do not succeed with it, and why so many orchards produce only debts and discouragement." (Bailey, *Cyclopedia of American Horticulture*, Vol. 3, p. 1228.)

Of the various fruits so far cultivated at Pūsa, peaches have grown with the greatest rapidity and have been the first to come into bearing. Although the varieties grown are only Indian sorts, the fruit, both in quantity and quality, has been far superior to that ordinarily grown in the plains of India. In response to numerous requests, a short account is given below of the experience so far gained on the growth of peaches at Pūsa.

Varieties.—In the western peach plot there are now six varieties, Hakim, Country No. 4, Country No. 3, Country No. 2, Country No. 1 and Hardoi, the plants of which were raised at the Botanical Gardens at Saharānpur. Of these Country Nos. 1 and 2 are the earliest, but an attempt is being made to find still earlier varieties in which case the later varieties will be replaced. Single trees of these varieties are also grown in the variety plot in Pūsa, but those in the western peach plot always come into flower several days earlier on account of the southern aspect.

Planting.—Although with great care the peach in India can be planted or transplanted successfully at any time of the year, it is best to plant them very firmly in previously moistened soil in the cold weather in January. The trees will thus be well established before the monsoon, and if planted on raised mounds will successfully withstand the heavy rains of July and August.

Soil, situation, drainage and cultivation.—As is well known, the peach thrives best in India in deep, sandy, well drained soils. In heavy loams, which are liable to waterlog in the monsoon, or in situations where the soil is subject to flooding, this tree does not grow well, and one heavy downpour after the monsoon is well established is sufficient to kill even large healthy trees. A southern aspect tends to promote early flowering and early maturity. Cultivation is of great importance. After the trees have been weathered, the whole surface should be dug over and a well aërated mulch of dry soil should be maintained till the crop is over. During the rains one or two cultivations greatly assist in keeping down weeds and in enabling the soil to absorb and store up the rainfall for the next crop. For stirring the soil round the trees the tool known as the *kodar* is very effective, the broader *kodali* being used between the rows.

Watering.—No rule can be given as to the amount of irrigation water that should be applied to the peach. The grower must learn to read his practice in the plant itself. Flowering is expedited by a copious irrigation applied just as the fruit buds begin to swell. After this the amount and frequency of watering will depend on the available soil moisture and the rainfall. After some experience the water requirements of the tree can be determined by observing the leaves. The last watering should be given just as the fruit begins to swell, and after this no further irrigation is desirable. Too much soil moisture and damp air during the picking of the crop are exceedingly injurious to the quality and keeping qualities of the peach so that great judgment is required to ripen off the crop to the best advantage.

Pruning.—The peach makes such a large amount of new growth every year in Bihār that special means have to be taken to regulate this and to mature the bearing wood for the next year's crop (Plate 5). The method of pruning to be adopted in the peach is determined by the vigour of growth. The system in use at Pūsa, where the trees grow with a more than extraordinary vigour, is a combination of light root-pruning and branch-pruning. The vase form of tree is the ideal aimed at, about five or six main spreading branches being allowed to develop from six to eighteen inches above the ground (Plate 4). It is best to allow these main arms to come off not at the same point, but one above the other so as to prevent splitting of the wood towards the end of the crop. These main branches are decided on as soon as possible after planting and any subsidiary shoots which arise are rubbed off. A good deal of the future success of the tree depends on the proper choice and maintenance of the main branches. The annual growth is shortened back considerably after the weathering operation is over, the middles are cleared and all unnecessary and interlacing twigs are cut out. The lower and central portion of the tree is kept clear and the crop carried on the circumference. The roots are exposed to a distance of five or six feet from the tree during October and are left open to the air till pruning time in December.

Plate 4.

An experimental Peach Plot at Pūsa.

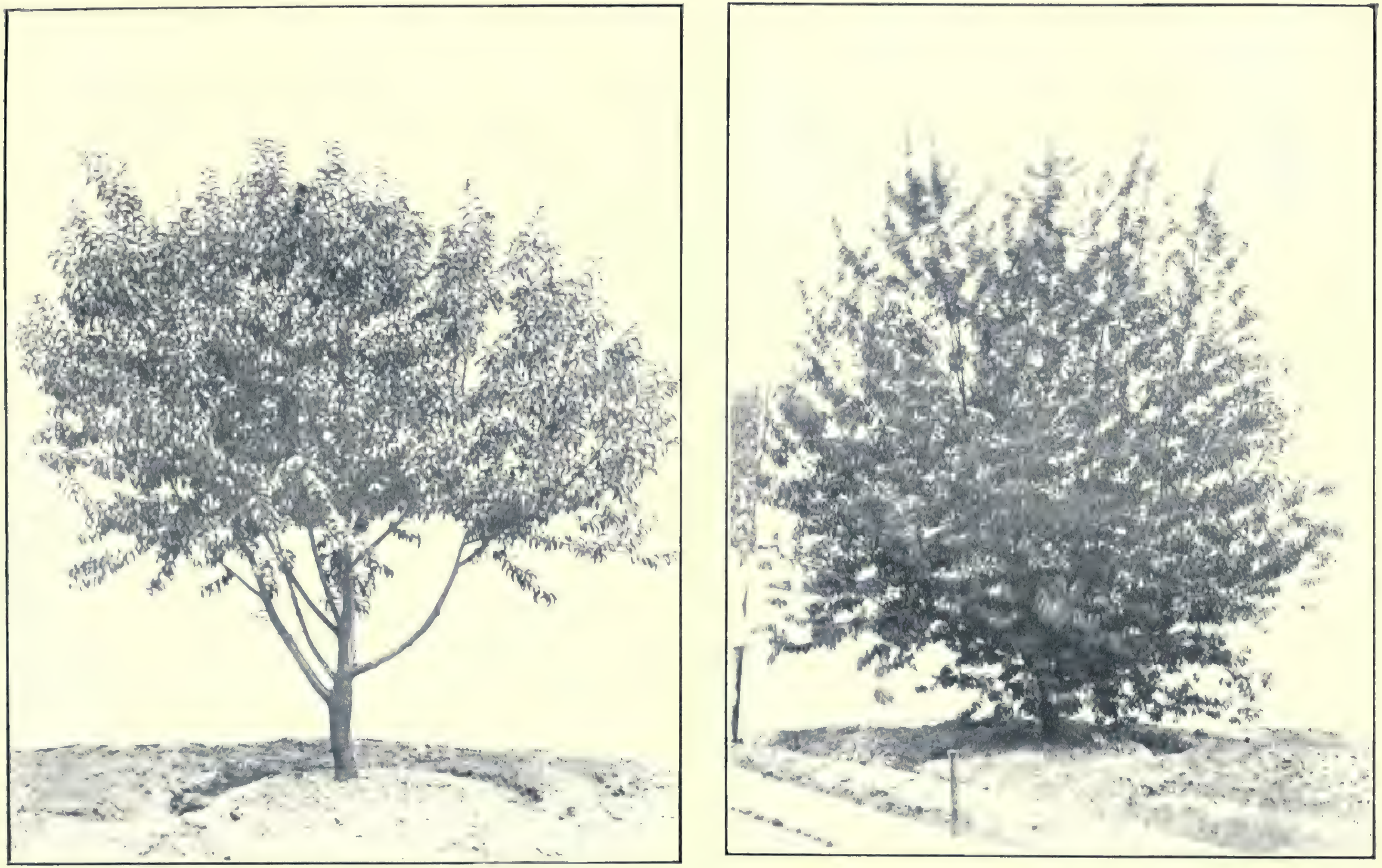

Plate 5.

Pruned. Unpruned.

The effect of Pruning on the Development of the Peach Tree.

This operation really results in a light root-pruning and has a great effect in reducing the number of fruit set. Experiments have been planned to determine whether the cutting back of about 25 per cent. of the larger roots at weathering time would not be an advantage in checking the growth of wood and strengthening the branches of young trees. The annual growth and digging in of a crop of *san* is not altogether an advantage with the peach as this proceeding increases considerably the growth of wood and foliage.

Management of the crop.—The average number of fruits set in 1909 (the third crop) was about 3,500 per tree which is much more than a four-year old tree can carry without breaking the branches and ruining the shape of the tree. Most of these fruits have to be picked off at thinning time and thrown away, the number left being about 750 to 1,000 per tree which is about the maximum load possible. Any number left on above this results in the bending and breaking of branches, to loss by dropping and to late ripening. Properly thinned trees ripen much more uniformly and quickly than unthinned peaches, while the quality and size of the fruit greatly improves. The fruit also improves both with the age of the tree and also with the age of each crop, the peaches which ripen first each year being much poorer in quality than those picked about the middle of the ripening period of each tree.

Picking.—The picking of peaches for marketing purposes is a matter which requires great judgment and is one in which it is difficult to train native labour. Time is required to impress on the average Indian picker the difference in handling required by delicate fruits like peaches and vegetables like potatoes. It is still more difficult to train him to judge the proper ripenness of the peach by the colour on the shady side of the fruit. Bright boys are best for this work and they improve considerably with time, but the difficulty of training Indian labour up to the standard required for the best results will always be a real one.

Great care should be taken to pick up and destroy all windfalls as these often contain the maggots of the fruit fly. As in other peach-growing tracts the damage done to the ripening crop by insects has to be borne in mind and guarded against, and one of the remedies is to destroy at once all windfalls. The question of finding a practicable remedy against this pest is now being taken up by the Entomological Section at Pūsa and it is hoped that as a result of these investigations an efficient remedy will be discovered.

Packing.—The greatest difficulty in peach-growing in India is to market the crop to the best advantage. In the plains the earliest peaches are not ripe till the end of May while most of the crop ripens in June. Both the day and night temperatures at this period are very high and picked fruit rapidly spoils. In India there are no facilities such as refrigerator cars as there are in the United States and the ordinary railway facilities for the rapid and efficient transport of perishable fruit have not yet reached a high standard. Another difficulty is the short picking season. As has already been mentioned the rise in humidity which accompanies the setting in of the easterly winds, which precede the monsoon current, leads to a rapid deterioration of the crop and the destruction of the carrying power of the peach. The problem of sending peaches a three or four days' journey in India with several transhipments preceded by a seven miles' journey to the railway in bullock carts was therefore one not to be undertaken lightly. Preliminary trials were made in 1908 and a large amount of experience on the difficulties of the operation was obtained. The majority of the consignments sent that year were more successful than was anticipated and for distances up to two days the fruit arrived in a satisfactory condition. These preliminary trials showed three points very clearly, (1) the impossibility of sending more than one layer of fruit unless an artificial support were placed between the layers, however short the journey; (2) the necessity of preventing one fruit from damaging the others by wrapping each fruit separately in thin paper; (3) separate compartments for each peach for very long journeys and where it is necessary for the fruit to arrive in first class condition.

In 1909, a method was devised and successfully tested by which the fruit could withstand a journey of 72 hours without deterioration when booked in the ordinary way. The best packages for peaches that could be devised with the materials and labour available at Pūsa were circular flat-bottomed bamboo baskets about 5½ inches high, fitted with a flat lid. Into these two tiers of small circular bamboo baskets for the single selected peaches were fitted, the two tiers being separated by a flat circular open work bamboo partition which can be dropped into the basket to serve as a floor for the second tier of small baskets (Fig. 3). The lid of the basket when wired on serves to secure the upper tier and also to keep the whole basket and its contents rigid. Each basket contains about 25 small baskets and thus serves to carry that number of fruits.

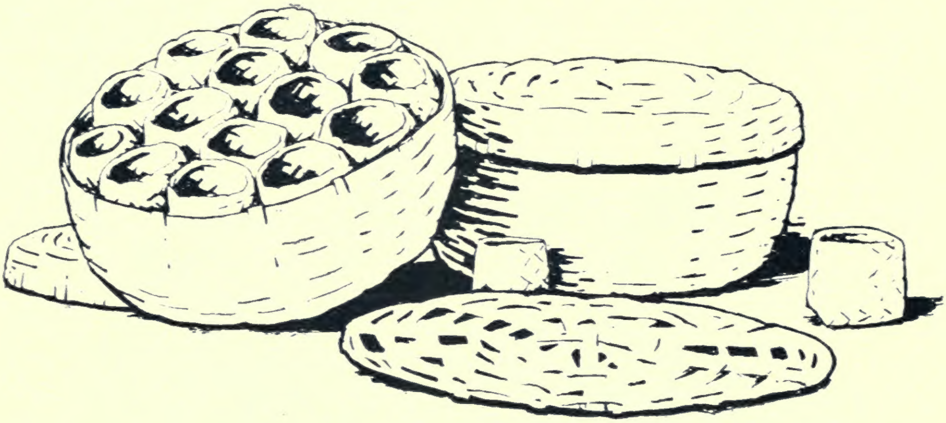

FIG. 3.—Bamboo peach baskets.

Picking takes place at daybreak about 4 A.M. when the temperature is near the minimum and the fruits are coolest. They are most carefully picked into flat baskets containing a layer of withered leaves to prevent bruising and when one layer deep are carried to the packing tables in the plot. Here the best fruits are picked out, wrapped in thin blue paper and packed in the little baskets with a small quantity of *san* fibre to prevent shaking and bruising during transit. The paper and *san* fibre besides absorb part of the moisture given off by the fruits during the journey while the open work nature of the package promotes ventilation. Sent in this manner peaches reached Simla in excellent order and withstood the journey of three days. This transport involved a journey of seven miles in a bullock cart to the railway, the crossing of the Ganges in a ferry steamer, and eight changes between the garden and their destination. With proper care in picking and packing and with no other materials or labour than is available in the plains it is possible therefore without the aid of ice cars to do much in sending the most delicate fruit to distant markets in the plains of India.

Experiments were also made in which ventilated wooden boxes were used instead of baskets for the outer package. In this case the small inner baskets were made square instead of circular. The results showed that boxes do not allow of sufficient ventilation and that the flavour accordingly suffers. These wooden boxes are much more expensive and more difficult to procure than bamboo baskets and their use was accordingly discontinued. Peat was also tried instead of *san* hemp as a packing material, but it did not prove so satisfactory or so attractive as the more easily obtained fibre.

For journeys up to 24 hours which do not involve a large number of changes such an elaborate method is not necessary. Under these circumstances it is sufficient to pack the fruit one layer deep in flat baskets, each fruit being wrapped separately in paper with a layer of withered leaves above and below. Fresh leaves cannot be used for packing as they are found to heat when closely packed and to unduly hasten the ripening of the peaches. The moisture they give off also tends to deteriorate the fruit. Care must be taken however to make the packing tight enough to prevent movement. Two of such baskets can be wired together to reduce the number of separate packages, or four or more can be sent in light openwork crates. Properly packed such baskets will reach Darjeeling in good condition.

The experience gained at Pūsa in peach-packing while demonstrating the great possibilities which are now within the reach of the grower nevertheless clearly prove that, however excellent the packing may be, the first condition for success is the care taken in picking to select the fruit at the right stage of ripenness and to prevent even the slightest damage in the garden itself. To travel three days under Indian conditions picking, grading and packing must be carried out without even the slightest bruising.

In carrying out the peach packing experiments in 1908 and 1909 much valuable help has been rendered by several correspondents. I take this opportunity in acknowledging in particular the assistance given by the Hon'ble Mr. J. G. Cumming, I.C.S., and by Mr. W. R. Gourlay, I.C.S., with regard to consignments sent to Darjeeling and Calcutta, to Mr. H. Davies in connection with fruits sent to Lucknow, to Mr. A. C. Dobbs of Bhágalpur and to Mr. J. Mollison, Inspector General of Agriculture in India, with regard to consignments sent to Simla.

PŪSA;
August 1909.

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"Indian Insect Life" by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Rs. 20.